

## 13. Incorporating MBSE into SoS Engineering Practice

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### Abstract

The engineering of complex systems-of-systems (SoS) is one of the main challenges facing Defence in the development, acquisition and implementation of integrated warfighting capabilities. SoSs are ubiquitous within Defence, yet there is currently little effort to engineer these systems and capabilities.

This presentation explores the nature of SoS, SoS engineering (SoSE) and the potential for MBSE to support SoSE. It includes a discussion of:

- 1) an understanding of military SoS in terms of its variety, formation, evolution and complexity;
- 2) an understanding of SoS activities throughout lifecycles and in evolution;
- 3) potential roles of MBSE in and relation to SoSE practice; and
- 4) key challenges and opportunities for applications of MBSE for defence SoSE.

Some important issues and features of SoS are explored, including military SoS variety, different SoS perspectives, SoS processes and SoS complexity and well-being. SoSE engineering is discussed, addressing the difference from traditional systems engineering and the US DoD approach to SoSE. Incorporating MBSE into defence SoSE practice is shown to be a necessary, albeit challenging, step in developing practical approaches to SoSE. This will require improvements and extensions of MBSE concepts, processes and tools in order to adequately and successfully address SoS challenges and issues.

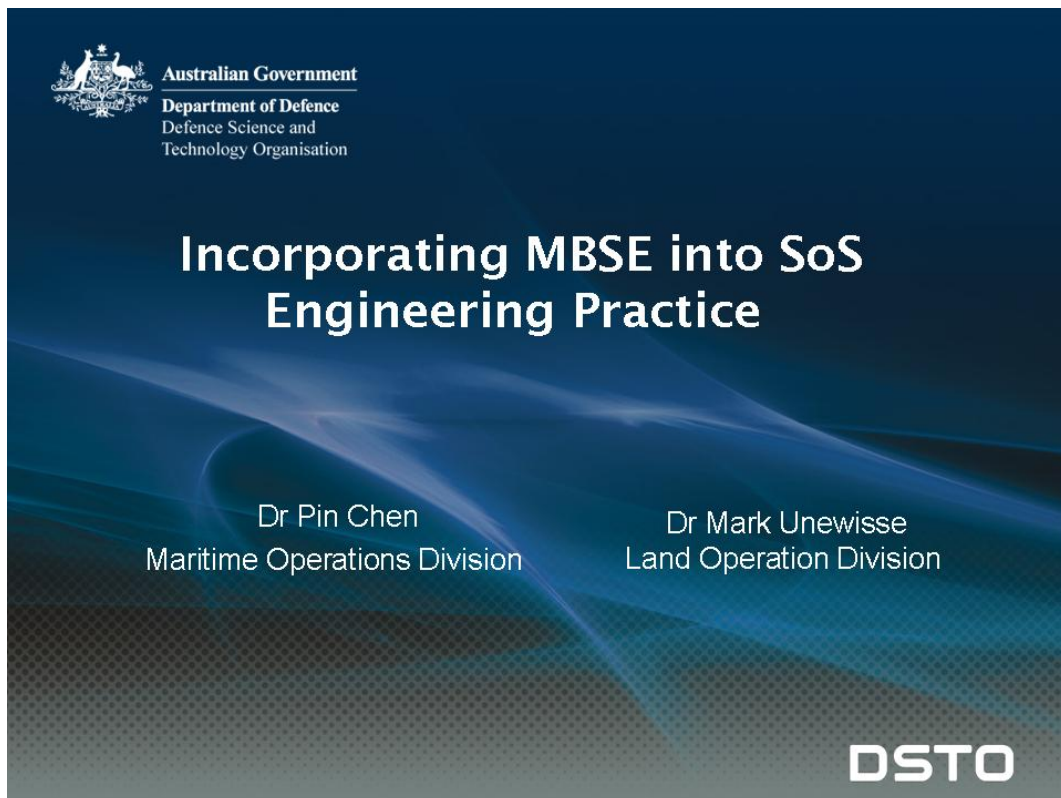
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14. ABSTRACT <b>The engineering of complex systems-of-systems (SoS) is one of the main challenges facing Defence in the development, acquisition and implementation of integrated warfighting capabilities. SoSs are ubiquitous within Defence, yet there is currently little effort to engineer these systems and capabilities.</b>					
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## Presenter Biographies

**Dr Pin Chen** is a Senior Scientist in Maritime Operations Division, Defence Science & Technology Organisation (DSTO). Dr Chen's main research interests include Architecture Practice, Systems Engineering for SoS, complex systems design, and complexity management. Dr Chen joined DSTO 1996 after he completed his Ph.D. in Computer Science at the Australian National University. Previously, Dr Chen led research tasks and studies in several fields, including architecture practice study, architecture information model development for architecture repository, SoSSE, and Unmanned Underwater Vehicle (UUV) cooperation modelling and design.

**Dr Mark Unewisse** is a Principal Research Scientist with the Land Operations Division of the DSTO, leading the Land Capability Integration program. His 28 year career with Defence has spanned: submarine and surface ship simulation systems; infrared optoelectronic systems; Land force C2 systems; military experimentation; Army aviation; Land and Joint Fires; Combat Vehicle Systems; Land NCW; force-level integration; force protection; and supporting the RAAF Combat Support Group. In addition, Mark has undertaken a wide range of corporate and leadership roles within DSTO. Mark's current research efforts include: system-of-systems integration, tactical land Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) and the implementation of networked force capability.

## Presentation



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## Overview

What are SoSs?

SoS Engineering

Potential Role of MBSE in SoS Engineering

A Challenge for MBSE

Conclusion

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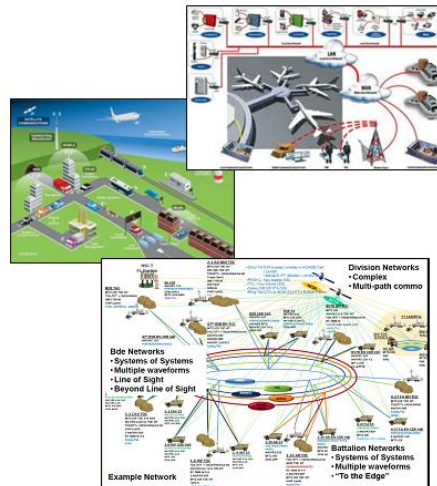
## What are SoS?

Collection of heterogeneous systems that work together to deliver a larger scale emergent behaviour, characterised by:

- Operational Independence of Elements
- Managerial Independence of Elements
- Evolutionary Development
- Geographical Distribution of Elements
- Networks of Systems

SoS are all around us

- Civil
  - Airport
  - Transport Network
  - Mines
- Military
  - Primary focus of this presentation



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Wide variety of SoS varying with:

- Form, function, scale, diversity, rate of change ...

Defence SoS can be view from multiple perspectives

- Platform Based
- System Based
- Capability Based
- Force Based
- Operational Based



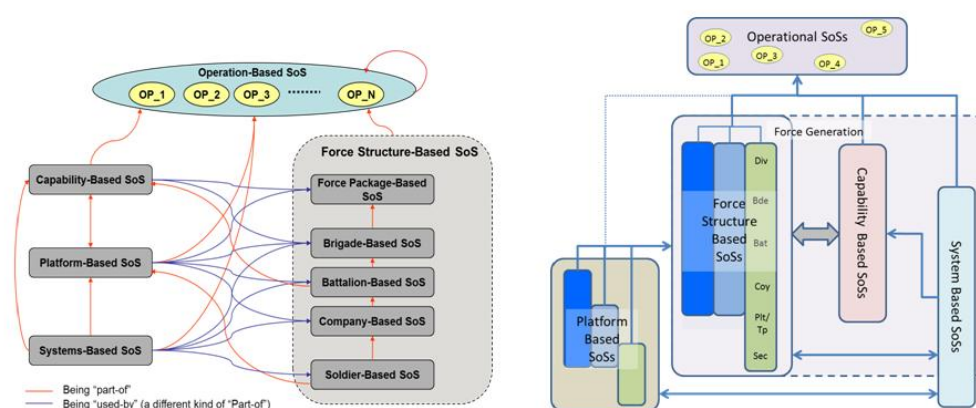


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## Interactions between SoS Perspectives

Interactions between the SoS perspectives

- Adding to overall SoS Complexity

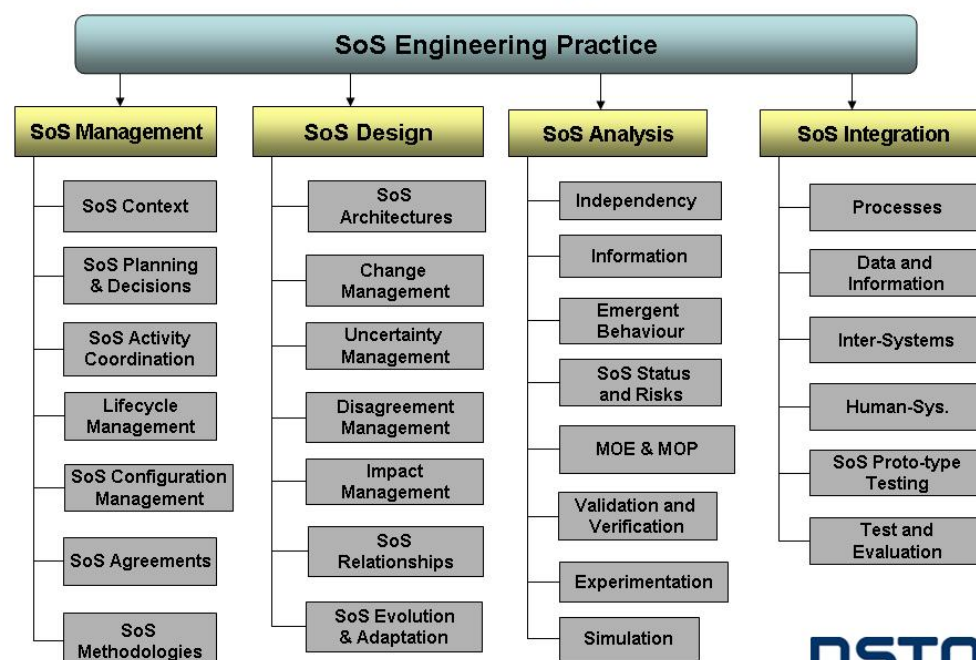


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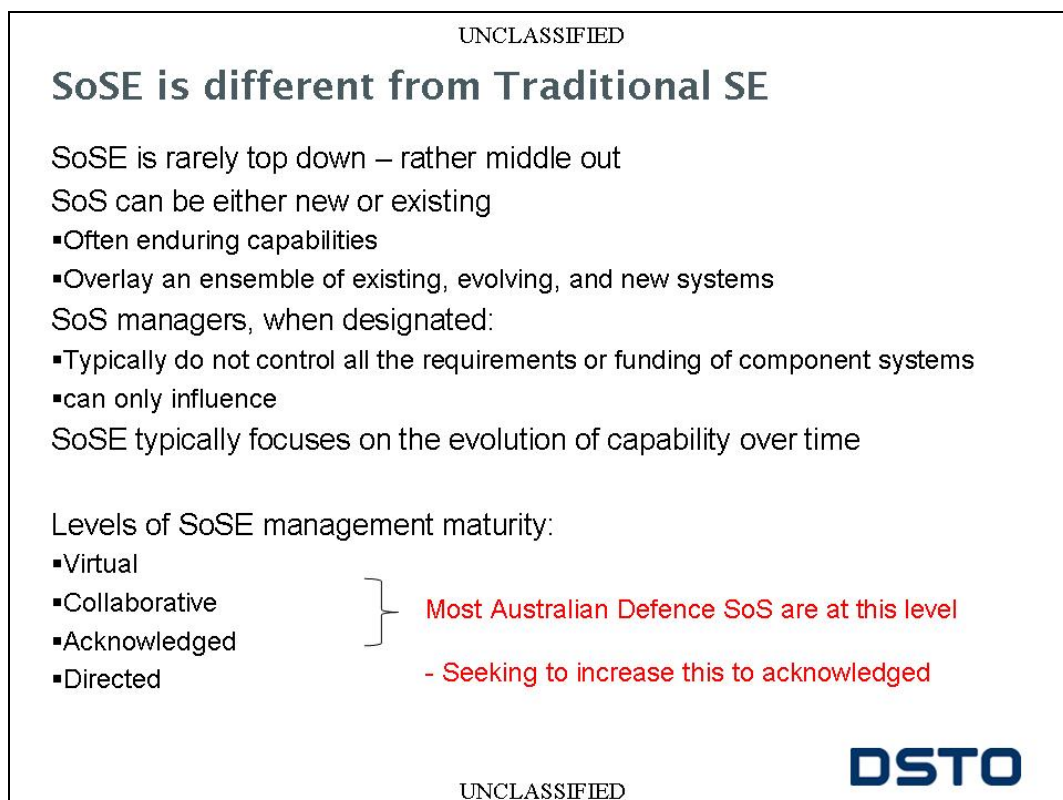
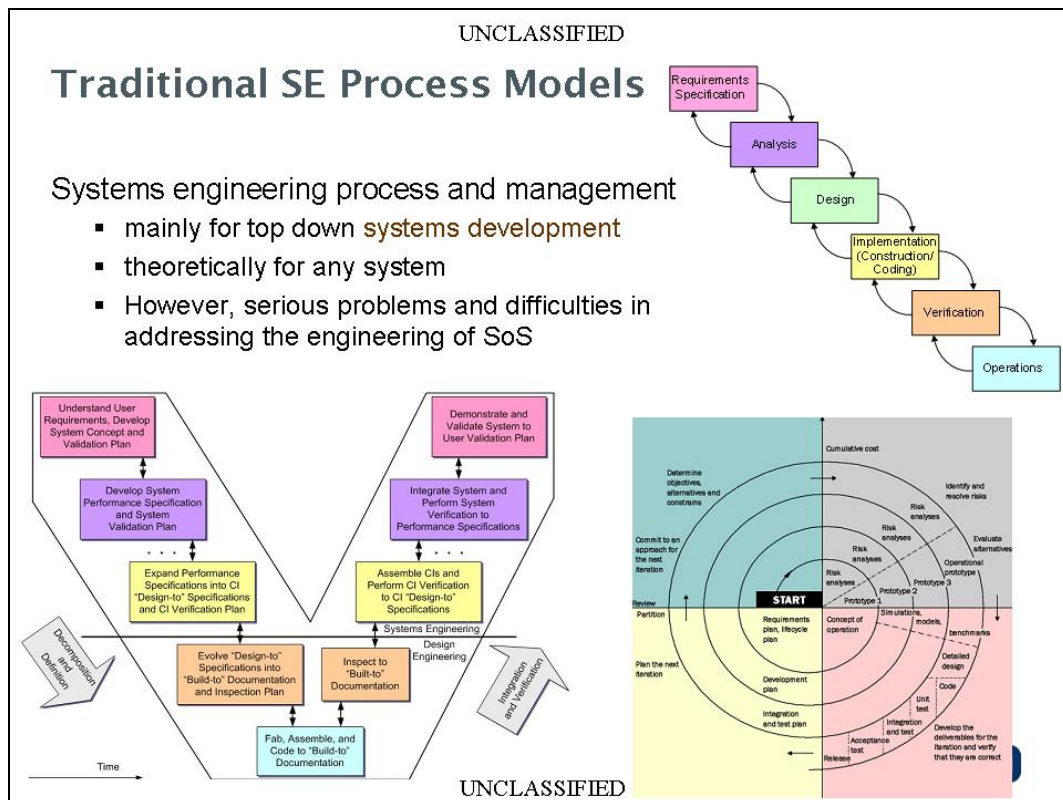
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## Defence SoS Activity Ontology (under development)



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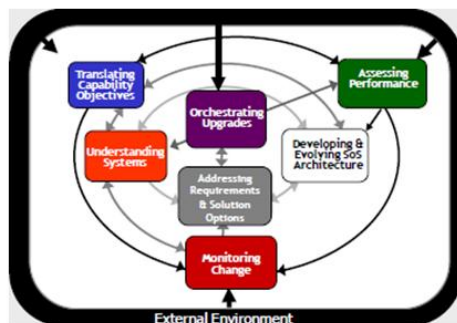


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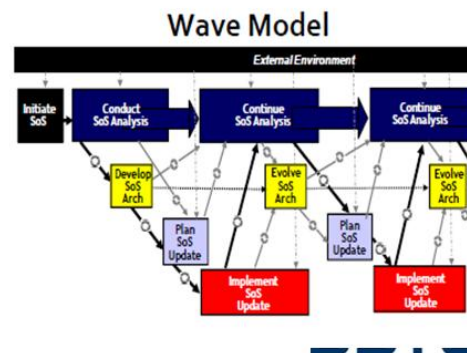
## US DoD Approach to SoSE

US DoD has identified 7 Key elements of SoSE:

1. Translating SoS capability objectives into high-level SoS requirements
2. Understanding the constituent systems and their relationships
3. Assessing extent to which SoS performance meets capability objectives
4. Developing, evolving and maintaining an architecture for the SoS
5. Monitoring and assessing potential impacts of changes on SoS performance
6. Addressing SoS requirements and solution options
7. Orchestrating upgrades to SoS



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## Managing SoS Complexity and Well Being

US DoD outlines part of what is required

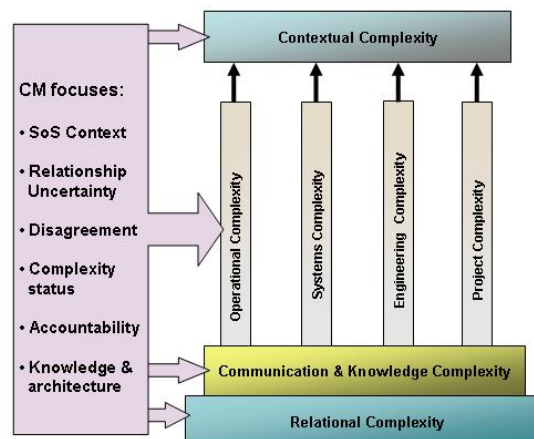
Still have a range of outstanding challenges for SoSE

Managing the Complexity of SoSE

- SoS variety and relations
- Multiple scales
- Unmanageable documentation based SE processes at SoS scale
- architecture management
- Knowledge management
- effective orchestration & coordination
- accountability management
- Nested concepts purposes
- Multidisciplinary view of SoS

Monitoring the 'Well Being' of SoS

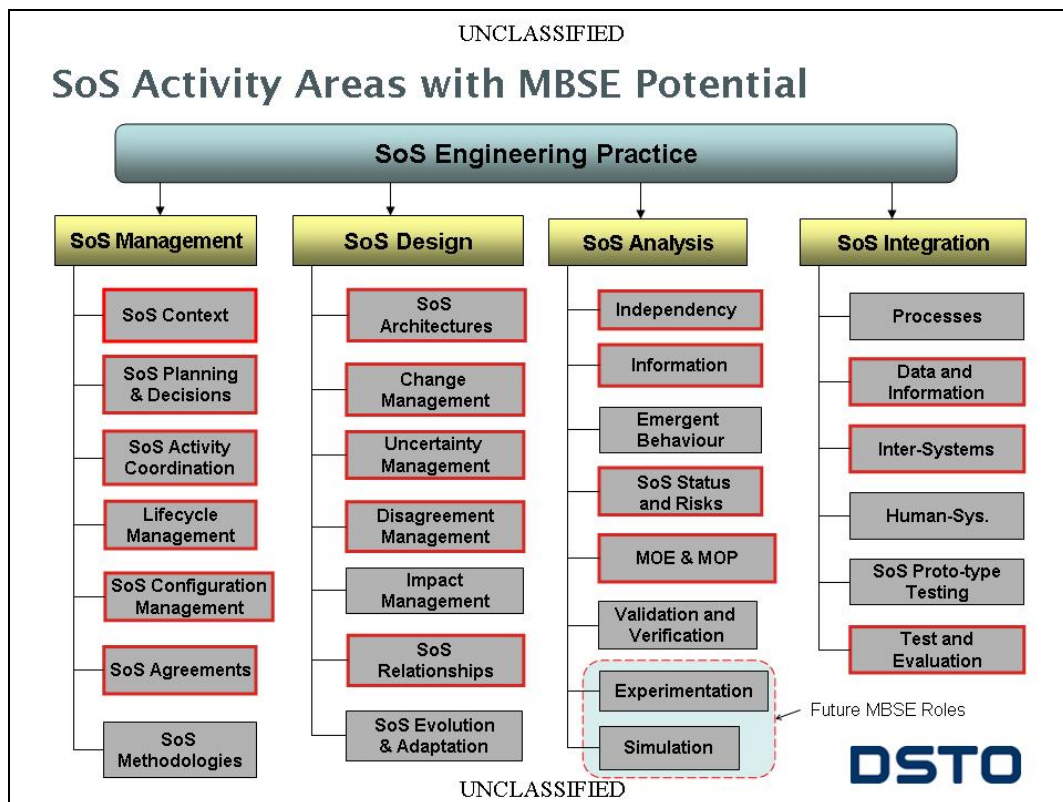
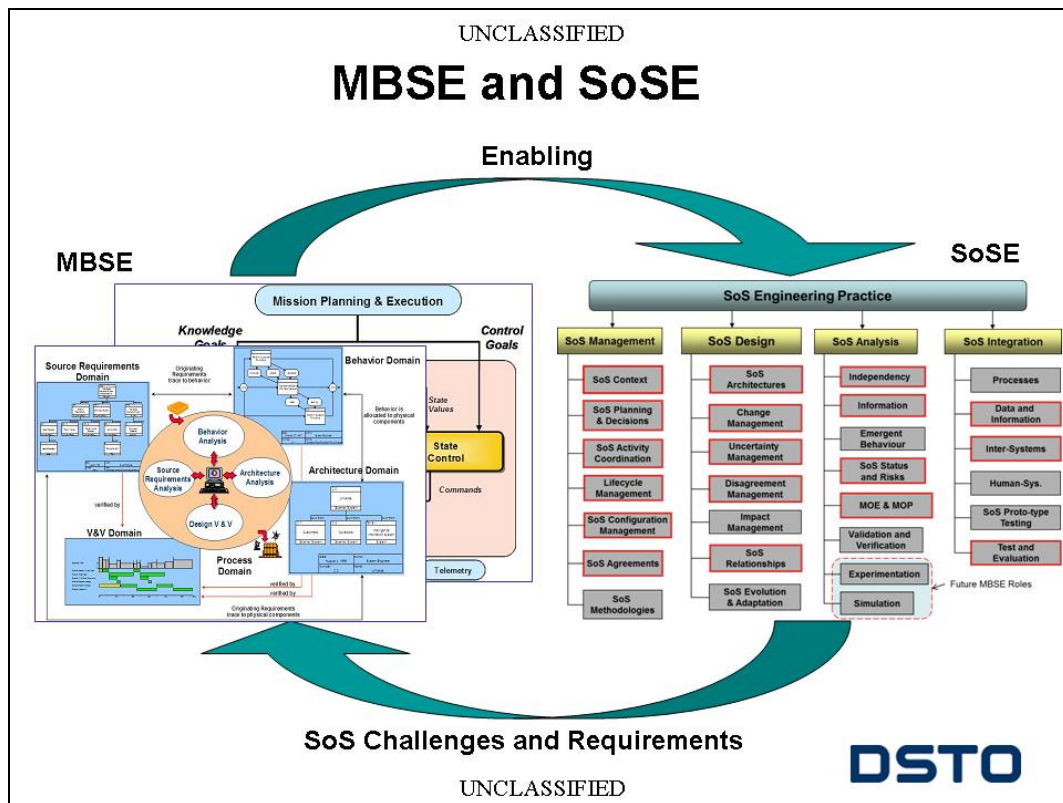
- Current
- Evolving
- From multiple perspectives



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## MBSE Support and SoS Perspectives

### Platform Based SoS

- Similar to standard major project SE use of MBSE
- “Imperial projects” taking lead for major elements of SoSE

### System based SoS

- Networking / Information system “glue” projects
  - Generally **Virtual** or **Collaborative** but moving to **Acknowledged** SoS
- MBSE to support engineering & management support across many projects
- High impact, particularly for Joint and Land

### Capability based SoS

- CDG/DMO SoS and service based SoS
- MBSE to support SoS synthesis and engineering of multiple component projects
  - Managing and applying lessons learnt
  - Generally **Virtual** or **Collaborative** SoS management, some **Acknowledged** SoS

### Force based SoS

- Potential to use MBSE to support force design trade-offs (?)

### Operational based SoS

- **Directed** SoS, but with little engineering design
  - Potential to use MBSE to support force design trade-offs
- MBSE has a role in configuration control and certification

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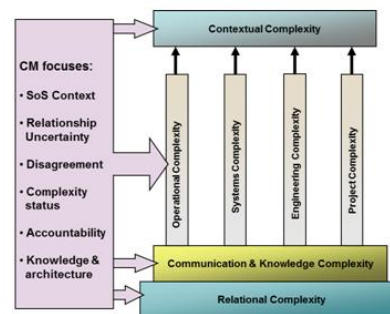
## MBSE Support to SoS Complexity Management

### Need an integrated SoS approach

- Cross project knowledge
- Managing the volume of data
- Common methodology

### MBSE provides potential to:

- Establish SoS standards and processes
  - Generate consistent component artefacts
  - Enable synthesis of SoS artefacts
- Manage web of cross-project
  - Interdependencies
  - Agreements
- Support SoS design trade-offs
  - Central tool for managing each ‘SoS Wave’
- Monitor & manage SoS status and Well Being
- Manage and track status of large numbers of component systems
- Understand impact of changes from component systems on SoS



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## Building Upon Existing Defence SoS Communities

Defence has established SoS Capability communities (but currently with only limited examples with SoSE), such as:

- Joint Fires
- Joint ISR
- Amphibious
- Base Protection
- Counter IED'
- Force Networking (Glue)
  - Particularly Tactical Land Force Networking



Seek to build on these communities and add the missing SoSE component

Complexity necessitates an MBSE based approach

- Requires development of MBSE tools and stakeholder education

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## Challenge for MBSE Community

Build the MBSE tools, processes & practices for SoSE

Start applying MBSE to key SoS test cases:

- Amphibious Capability
- Land Force Networking
- Certification of Operational Forces

Establish a partnership with capability development community for SoSE

- Note also called "capability engineering"

Time is right to address SoSE

- Lessons from large projects have grown the need for capability engineering
- Initiatives in CDG – DGICD to address



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## Conclusion

SoS present a major challenge for Defence engineering

- Complex, with a large number of component systems
- Different from traditional SE
  - Often enduring systems developed in 'Waves'
- Multiple Perspectives on SoS

Need MBSE in order to:

- Establish SoS standards and processes
- Manage the volume of SE artefacts
- Manage web of cross-project Interdependencies & Agreements
- Support SoS design for each 'SoS Wave'
- Monitor & manage SoS status and Well Being
- Understand impact of changes from component systems on SoS

Window of opportunity to establish a MBSE in Defence SoSE

Initially address a few test cases:

- Amphibious Capability
- Land Force Networking
- Certification of Operational Forces

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